DEVELOPMENT OF AN IMPROVED HIGH INTENSITY HIGH RESOLUTION SCREEN FOR REAR PROJECTION

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TABLE OF CONTENTS

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TABLE OF CONTENTS

LETTER OF TRANSMITTAL

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[redacted] STAT

[redacted] STAT
Main Post Office Box 2143
Washington, D.C.

Subject: High Resolution Projection System

Reference: [redacted] Letter Proposal 3-1303 STAT
Proposal 3-1303A

Gentlemen:

Thank you for your verbal request for a further proposal on a high resolution projection system. The present proposal is basically a research and development program centered on the development of a suitable fluorescent screen for such a system. The basic idea of this proposal has been tested by [redacted] STAT [redacted] and a patent has been applied for. The development of the STAT screen will be taken to the point where it is readily reproducible. In the course of the program a suitable projector and optical system will be designed to excite the screen.

A complete cost breakdown for the work specified is attached, together with a time schedule. The costing of the program is based on a cost-plus-fixed-fee contract under the Armed Services Procurement Regulations, appropriate details are enclosed.

The basic research work on the screen materials will be done at the [redacted] STAT [redacted] as they are ideally equipped to do this work. This STAT work will be a subcontract; however, the overall program control and direction remains with [redacted] The [redacted] and located close to STAT our facilities enabling control and liaison to be easily maintained.

[redacted] will submit monthly progress reports, in addition to a final report, on STAT the findings of the whole program.

Just prior to the submission of this proposal we received your samples of Type 5247 and 5430 film. We have run density versus wavelength tests on these and the graphs are included in the Appendix under Technical Data.

[redacted] STAT

[redacted]
Washington, D. C.

20 Septemb STAT 53
Page 2

At your request, [redacted] has limited the distribution of information regarding this p STAT posal to the home office in [redacted] STAT

Should you have any questions regarding this proposal, or require either additional information or a local contact, please do not hesitate to contact us.

Sincerely,

[redacted] STAT

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COST QUOTATION

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TERMS AND CONDITIONS

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TERMS AND CONDITIONS
(Cost-Plus-Fixed-Fee Research and Development Contract)

Terms and Conditions substantially in agreement with the Armed Services Procurement Regulations would be acceptable to [redacted] under STAT any Cost-Plus-Fixed-Fee Research and Development Contract resulting from this proposal.

It is requested that the following provisions be incorporated in the resulting contract:

1. "Stop Work Orders" Clause ASPR 7-404.5

2. Contractors Independent Research Programs

   a. Any invention made in the performance of any work by the Contractor under the Contractor's own product improvement program or the Contractors Independent Research Program, even though supported by an allowance of costs for such program as a part of the overhead costs hereof, will not be subject to the "Property Rights in Inventions" clause of this contract unless said work is identified in writing as being required in the performance of this contract.

   b. The concept contained herein is regarded properietary and [redacted] retains all rights to commercial applications of the concept. STAT

3. Payment - Net within 30 days after date of invoice.

4. Payment of the fixed-fee under this contract shall be made in monthly installments. Each installment shall bear the same proportion to the total amount of the fixed-fee as the proportion of work completed at the date of such claim bears to the total work called for under this contract.

5. Reimbursement and settlement of overhead expenses shall be on an actual rate as established by the cognizant Government audit agency. Pending establishment of the final overhead rates for any period, provisional reimbursement will be made on the basis of billing rates approved by the cognizant Government Auditor.

[redacted] STAT
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TERMS AND CONDITIONS (Continued)
(Cost-Plus-Fixed-Fee Research and Development Contract)

6. "Authorization and Consent" clause ASPR 9-102.2.

7. "Patent Rights" Clauses ASPR 9-107.1(a), 9-107.2(a) and 9-107.2(b).

8. Authority to Subcontract - Sole Source Subcontract Approval.

[redacted] is hereby granted approval to subcontract to STAT [redacted] STAT as a sole source subcontractor, a portion of STAT the work on a Cost-Plus-Fixed-Fee basis.

General - [redacted] cognizant Government Audit Agency is the Air Force Auditor STAT General in coordination with [redacted] Administrative Contracting STAT Officer, Headquarters, Los Angeles Contract Management District. [redacted] STAT [redacted] STAT

TECHNICAL DESCRIPTION

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1. INTRODUCTION

Our earlier proposal [redacted] Register No. 3-1303A, was for a system designed to increase the rate of information transfer from a projected film image to an observer. The proposal covered areas of research which would improve screen resolution by using new screen materials, new projection techniques and by investigating certain physiological responses. STAT

This proposal [redacted] Register No. 3-1303B is specifically for a research and development program to produce a high intensity, high resolution fluorescent screen of optimum performance for the rear projection of a black and white film image. The light source used for projection will be strong in ultra-violet as well as visible light. STAT

[redacted] requests that the concept contained herein, and the successful development of an improved screen be regarded as proprietary and retains all rights to commercial applications. STAT

2. OBJECT OF SCREEN RESEARCH AND DEVELOPMENT WORK

The object of this research and development work, as detailed below, is to produce a high resolution, rear-projection screen of improved performance.

The proposed screen will comprise a layer of fluorescent material on a glass-like substrate and will have a high degree of transparency to visible light. Tests will be performed to determine the optimum illumination of the screen to provide the maximum rate of transfer of information.

It will be illuminated by:

a. Ultraviolet light alone so that a visible linage may be formed on the screen.

b. Visible light alone so that an aerial image can be formed and transmitted through the screen and viewed by a supplementary magnifier in front of the screen.

c. A combination of visible and ultraviolet light, the aerial and visible linage as formed being brought to a focus in the same plane.

A projector lens corrected for the ultraviolet and the visible is necessary for the above experiments.

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3. FEASIBILITY DEMONSTRATION

To demonstrate the feasibility of the screen small samples a few inches square will be used. From these an initial evaluation will be made to determine image quality using ultraviolet light viewing.

Final evaluation of the best samples will be made using a projector having high-power ultraviolet and visible light sources and which will achieve the magnifications required in practice.

The above is discussed in detail in the following work statement.

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4. DETAILED WORK STATEMENT

a. Make necessary jigs and fixtures.

b. On a suitable, transparent glass-like substrate make trial coatings of zinc sulfide and cadmium tungstate by vacuum deposition. Coatings will be of zinc sulfide activated with copper, chlorine, phosphorus or arsenic, and of cadmium tungstate with tungsten or manganese activator.

c. In parallel with the above an extensive search of literature will be made to determine what (applicable to the project) has been done in this field and whether there are more promising materials which should be tried.

d. It is also proposed to make organic luminescent coatings of anthracene, fluorene, rubrene, diphenylcyclo-octatetraene and umbelliferone in an acrylic resin or a polycarbonate resin.

e. These samples will be tested using ultraviolet stimulation and measurements made of visible emission brightness.

f. An evaluation of the best of these coatings will be made to determine image quality using a small ultraviolet projector which is currently available and whether sufficient resolution and brightness can be obtained for direct image viewing.

g. A feasibility demonstration will be carried out using a projector with a lens corrected for ultraviolet and visible light. The film frame will be projected on an area of at least 30 by 30 inches and an evaluation will be made of the visible image, the aerial image and the composite image formed by the ultraviolet and the visible light.

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4.1 CHARACTERISTICS OF THE FILTERING

a. For transmission of ultraviolet (UV) in the region required to excite a phosphor sensitive in the region 3500-4000 Å. This would be a combination absorption filter having a characteristic as shown in Figure 1. The broken line is transmission by the lens materials and the full line is transmission of Corning 7-54 filter. The shaded area represents transmitted UV.

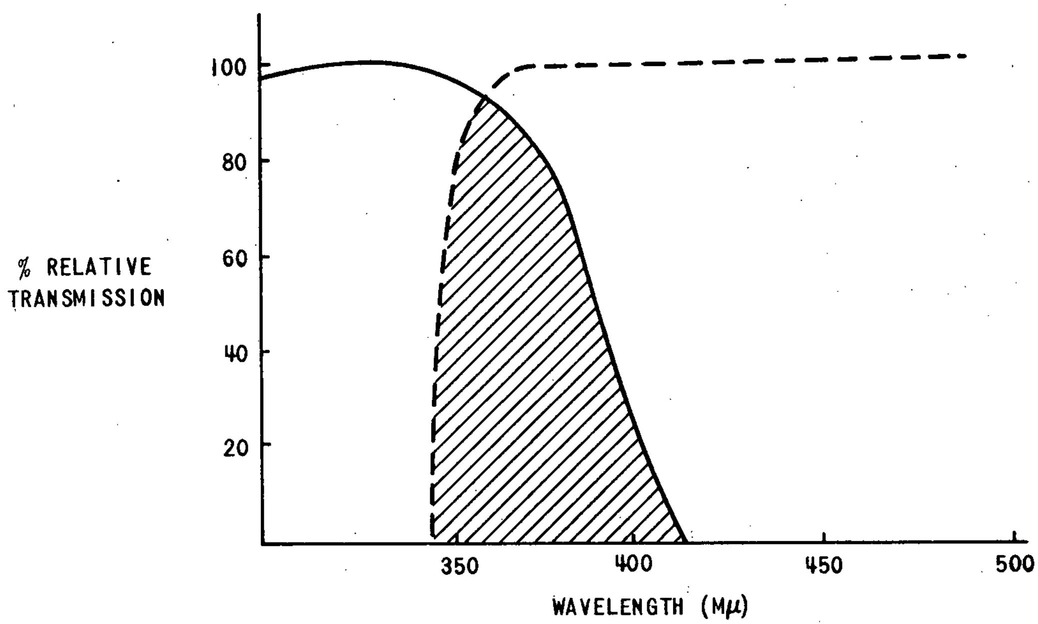

FIGURE 1
Percent Transmission for Corning
7-54 Filter and Lens Material

This combination would be used if it proves feasible to view the overall scene and to study in detail an area of interest using luminescence of the screen only as discussed in 2.(a).

b. For transmission of both UV for exciting the phosphor, and visible for specular viewing, the filtering curve in Figure 2 would apply. Here the broken line is the lens and full line is a filter-like Balzer 1256/283 CALFLEX B1/K1.

4.2 CONTRAST TRANSFER FUNCTION GOAL

Preparation of three types of luminescent screen is planned. These will be inorganic transparent, inorganic diffuse and organic transparent. Brightness of ultraviolet stimulated visible emission will be measured by a photocell. Resolution capability will be evaluated by standard resolution test pattern image observations.

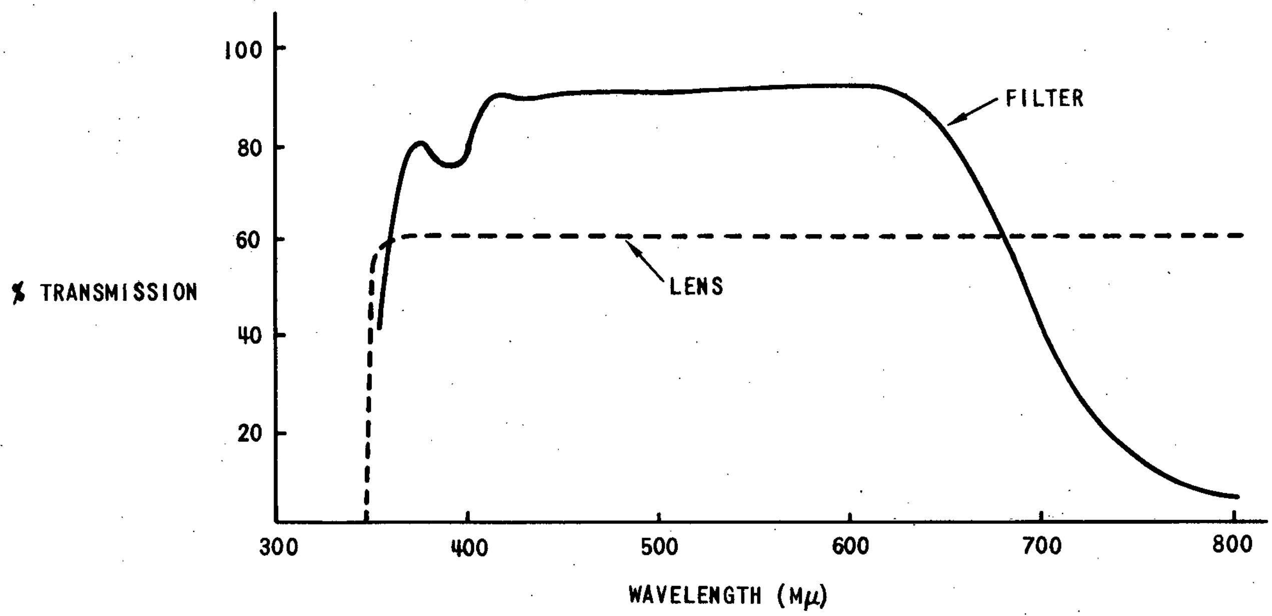

FIGURE 2
Percent Transmission for μv and Visible for Lens and
Filter Balzer 1256/283 CALFLEX B1/K1

To measure contrast transfer function would require use of a specialized microdensitometer, which we do not have. As the result of this program we shall be able to define the requirements for the apparatus to make these measurements. This may form the basis for a separate proposal in which we would undertake to compare performance of the screens produced in this work with those in the prior art.

4.3 FILM BASE AND EMULSION OPTICAL CONSIDERATIONS

Information has been obtained concerning Eastman 5427 Aerographic duplicating film which has a cellulose acetate butyrate base and also for Eastman type 8427 Aerial Recon. duplicating film which has a cellulose tri-acetate base.

Curves are shown in Figure 3 below, for spectral transmission of base alone and of processed unexposed base with emulsion. The curves show that transmission does not vary greatly throughout the spectrum of interest. Curves for other materials are included in the Appendix.

H&D curves of density versus exposure for various processing procedures (see Figure 4 below) show that, for faithful reproduction of the original film, the range of transmission of the film may be from 60% (D = .22) to approximately .1% (D = 3.0) or about 600:1.

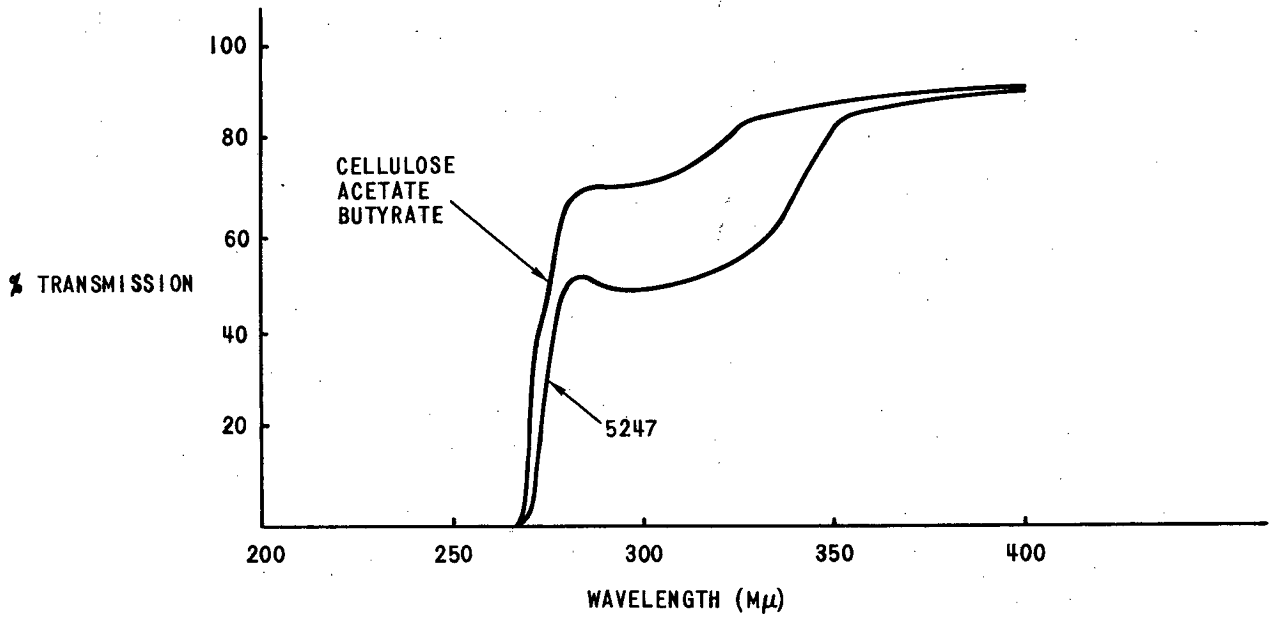

FIGURE 3
Percent Transmission versus Wavelength

4.4 PHOSPHOR CONSIDERATIONS

4.4.1 INORGANIC PHOSPHORS

A literature search for figures relating luminescent yield of phosphors for incident energy so far has yielded little information on transparent phosphors excited by near ultraviolet (3500 Å - 4000 Å). Extensive discussions are given for diffuse or crystalline surfaces which are commonly used for TV and instrumentation cathode ray tube phosphors. These phosphors are generally excited by electron beams and information relating to ultraviolet excited emission has been mostly qualitative. In general, manufacturers of phosphors regard ultraviolet stimulated visible emission as weak, compared to electron beam excited emission, yet it may be adequate for our purpose.

One reason for the weak emission of transparent phosphors is that a single passage of the ultraviolet does not allow much path length for absorption. For diffusion crystalline phosphors a much greater path length is traversed due to multiple internal reflections in the crystals. For transparent phosphor screens, emission of light measured in the direction of the viewer is about 25 to 50% of the total emitted by the phosphor.

4.4.2 ORGANIC PHOSPHORS

Organic luminescent materials have been investigated much more fully because absorption of ultraviolet and emission of visible and ultraviolet are used as a tool for analysis of organics. However some materials which luminesce in liquid solution will not do so in solid solution. For others the converse is true. Also increase of concentration in solution sometimes results in a decrease in emission.

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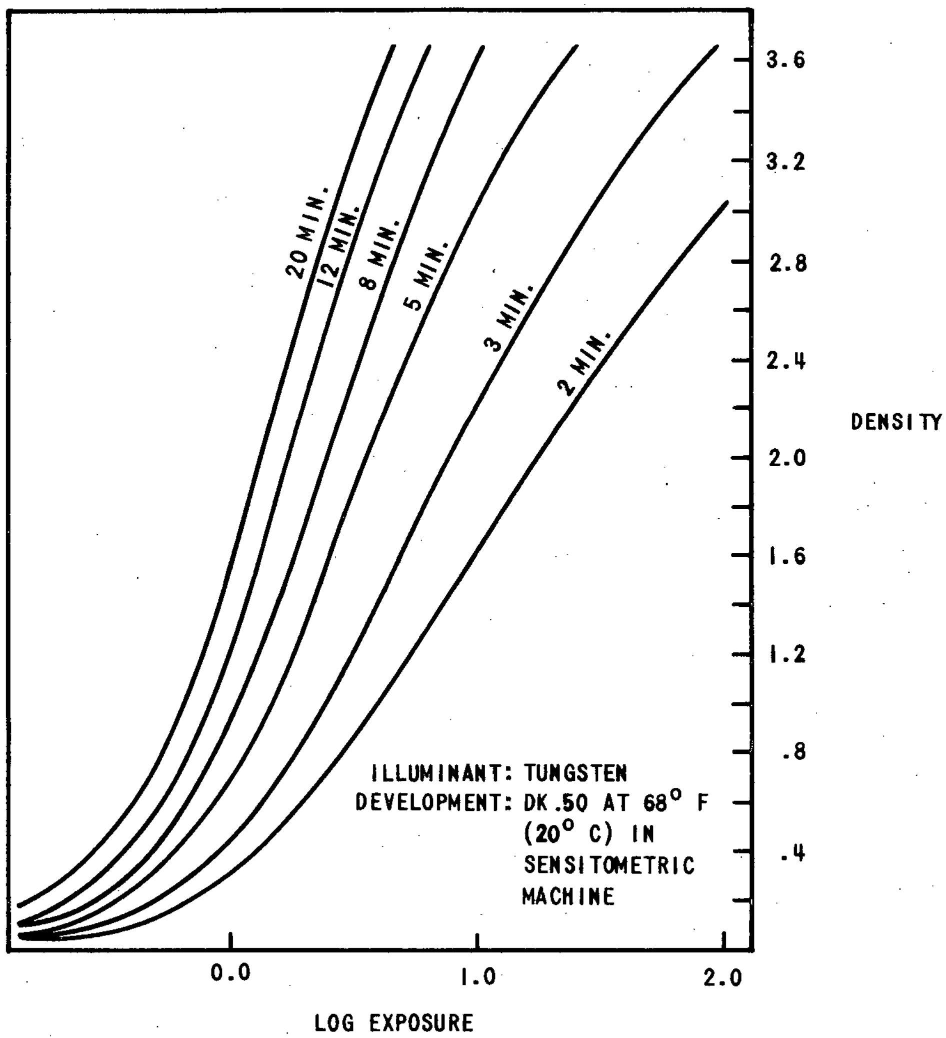

FIGURE 4
Percent Transmission versus Density

5. PROJECTION SYSTEM FOR FINAL FEASIBILITY DEMONSTRATION

In conjunction with the above work a projection system will be designed capable of handling up to a 2.5 KW light source and yielding ultraviolet as well as visible light, with suitable filters therefore, it will be possible to excite the fluorescent screen with ultraviolet or visible light or both.

To prevent damage to the film due to heat, infrared transmitting mirrors and infrared filters will be incorporated in addition to refrigerated air cooling as may prove necessary.

The projector will illuminate a screen area of at least 30 by 30 inches so that any fluoresent sample under test will receive the energy per unit area that would be experienced in practice.

In order to test the full capabilities of the screen, a projector lens will be designed so that the ultraviolet and visible light are brought to a sharp focus on the screen. The lens will therefore be corrected over the range from 3500°Å to 6000°Å and will also have a resolution of 200 lines per mm. The maximum magnification of the projector system will be approximately 50 times.

An additional optical system may be used in front of the screen so that quality of the visible linage formed by the ultraviolet and the aerial image formed by the visible can be evaluated both independently and together. A minimum of four spectral interference filters will be provided to select appropriate wavelengths for the viewing of the visible light.

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6. SUGGESTED FURTHER STUDIES BASED ON OUTCOME OF THE ABOVE WORK

Should successful single layer fluorescent screen samples be developed, follow-up work and studies should encompass:

a. The technique of making larger screens of approximately 30 by 30 inches should be mastered

b. Screen samples having multiple coatings should be developed and evaluated. Such screens could render density levels in the form of color.

c. The basic objective of obtaining maximum information transfer from a projected film image to an observer should be followed up using the maximum number of observer sensitivities.

For example, the intensity of light on a multiple coated screen could control the depth to which light penetrates. Using coatings flourescing at different wavelengths, and using color-separating filters, an observers perspective detecting faculty could discern density levels.

Other physiological responses, which were discussed in the previous proposal 3-1303A, and which could be applied to the viewing of a fluorescent screen, should be investigated in order to produce an optimum overall system.

7. PROGRAM SCHEDULE

The PERT diagram (Figure 7-1) depicts a summarized program outline. See Figure 7-2 for Program Organization.

At the end of the first 3 weeks of the program a sufficient evaluation of the initial coatings will have been made so that the design and procurement of projector parts can proceed.

Continued studies and work on experimental screen coatings will take place in parallel with the projector lens design, and projector procurement and assembly. This phase of the work will cover a period of thirteen weeks.

The time spent on the literature survey of screen materials etc., will be about 120 hours. This time will be spread over a period of 16 weeks as shown on the PERT diagram.

Final evaluation of the best screen using the projector with a 2.5 KW light source, and necessary filters etc. will take place over a 6 weeks period.

is uniquely suited to accomplish the tasks required in this proposal. A description of the background and facilities can be found in the Appendix.

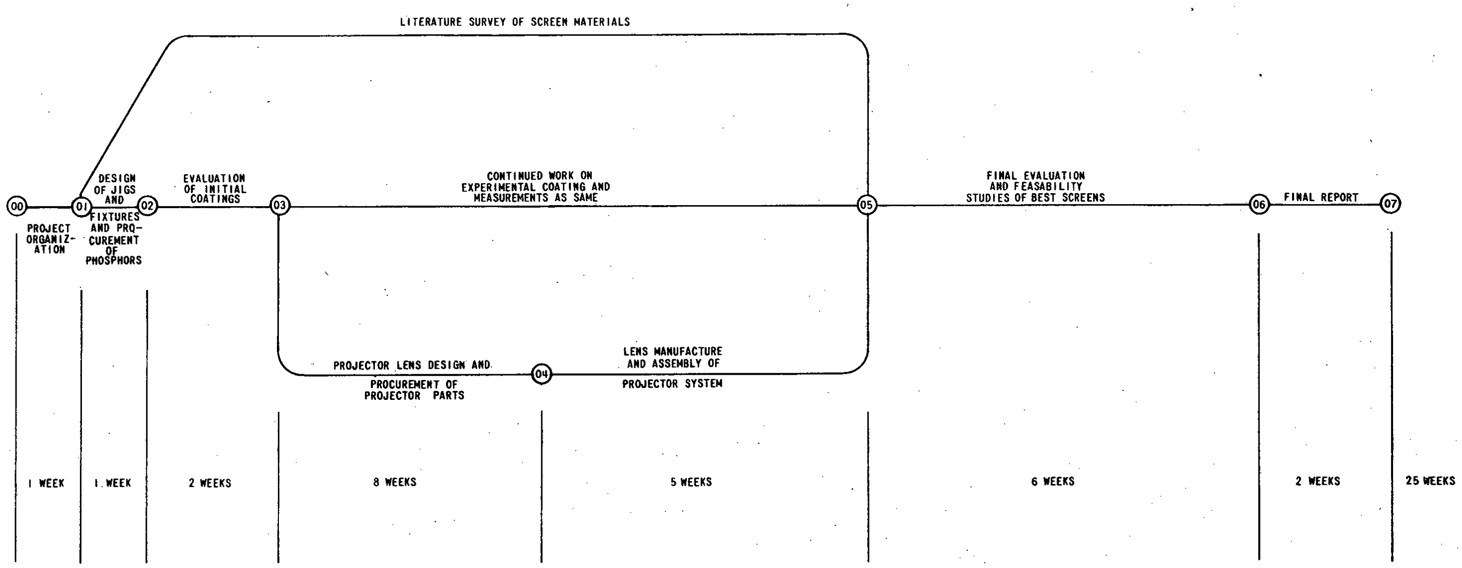

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FIGURE 7-1
Program Outline

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APPENDIX

Miscellaneous Properties

Section 11 ∘ Optical Properties

This section presents data on the optical characteristics of aerial films which might be of some use in the design of special photographic systems, or of value in the interpretation of effects. The spectral transmittance of film base and emulsion-coated films is given, together with typical values for haze, as it might affect the clarity of negatives, printing techniques, etc. The indexes of refraction of cellulose ester and Estar polyester bases are of practical importance in their effect on the fogging of aerial films by accidental edge illumination, and on image resolution.

A. SPECTRAL TRANSMITTANCE

The spectral-transmittance curves for cellulose ester and Estar bases, and for various aerial films which have been developed and fixed without exposure, are given in Figures 11–1, –2, –3, and –4.

Both types of base show a sharp cutoff in the ultraviolet region (Figure 11–1). The cellulose ester base does not transmit below about 270 millimicrons, or the Estar base below 315 millimicrons. In the visible region both types of clear base show excellent clarity with high, uniform transmission. In the case of the gray triacetate base the spectral transmission is affected by the dyes incorporated for antihalation purposes (Figure 11–3).

Estar and cellulose ester bases show high transmission in the near infrared region out to 2 microns wavelength (Figure 11–4). Between 2 and 15 microns there is considerable variation in transmission with wavelength. In this region the infrared absorption characteristics of the particular polymer are of value in analytical determinations of structure and composition, but are probably not of practical importance in photographic applications.

The transmittance values for emulsion-coated films developed and fixed without exposure show changes from the base curves in the ultraviolet and visible regions (Figures 11–2 and 11–3). The transmission is slightly reduced as a result of residual traces of backing dyes and emulsion silver. Transmission in the near infrared region is not significantly affected by the presence of the fixed-out, clear gelatin layers (Figure 11–4).

The data in Figures 11–1, –2, –3, and –4 are based on total transmission. Measurements comparing the total, or diffuse-light, transmittance with the specular-light transmittance show the latter to be only 2 to 3 percent less for the film bases and for films that contain no matte in the emulsion or gel backing. Where a matte is present in the fixed-out film, the specular transmittance averages 12 to 15 percent less than the total transmittance.

B. HAZE

Extremely fine particles dispersed in the film base or gel layers act just as atmospheric haze does in the scattering of light rays. "Haze" is defined as that percentage of transmitted light which, in passing through a sample, deviates from the incident beam by forward scattering, i.e.:

$$\%\ \text{Haze} = \frac{\text{Scattered Light}}{\text{Total Transmitted Light}} \times 100$$

It may be measured by a hazemeter or recording spectrophotometer, as described in American Society for Testing Materials, Method D 1003-59T.

Typical haze measurements for film bases and unexposed processed films are shown in Table 11–1. Both cellulose ester and Estar bases are quite free from light-scattering effects, and the haze of clear, processed films that contain no matte is generally less than 1 percent. In the gel-backed films a matte is incorporated to reduce intimacy of contact between laps of film and to avoid Newton's rings in printing operations. This matte results in haze values of 8 to 12 percent. The practical effect of this amount of light scattering is not ordinarily significant in the use of the films. Matte particles are not resolved except under conditions of very high magnification (80 to 100X). However, it must be recognized that haze might cause some slight loss of resolution in printing operations under very critical conditions involving specular illumination.

C. REFRACTIVE INDEX

The refractive indexes of film components are probably of practical interest only in very special cases where the design of systems requires recognition of this optical property. Typical values for refractive index are as follows:

		Refractive Index N_D
Cellulose Ester Bases		1.48
Estar Polyester Base		
Vertical axis	N_α	1.50
Perpendicular to major axis in plane of sheet	N_β	1.64
Major axis in plane of sheet	N_γ	1.66
Gelatin		1.50 - 1.54

A material which exhibits variations in refractive index in different directions is said to show birefringence. Because of the biaxial stretching of Estar base in manufacture, it exhibits this behavior. As shown above, the greatest difference in index of refraction is between the thickness direction and the plane of the sheet. Differences in the plane of the sheet, not necessarily in the length and width directions, are slight and generally less than 0.02. The effect of this slight difference in orientation on dimensional stability of Estar base is discussed in Section 9. The birefringence of cellulose ester bases is almost negligible, being of the order of 10^{-5}.

D. EDGE FOG

A very practical effect of the difference in refractive index between cellulose ester and Estar bases is in the extent of film fogging which may result from exposure of the film edges to light and consequent "piping" of the light through the film base. This is entirely separate from film fogging by accidental exposure of the emulsion surface to light.

When the ratio of refractive index of the gelatin coating to the base is less than 1.0, as in the case of Estar base film ($m = 1.54/1.64$), efficiency of internal reflection within the base is high over a wide range of incident angles. Where the ratio is greater than 1.0, as with cellulose ester base films ($m = 1.54/1.48$), efficiency of internal reflection is much lower. Therefore, much of the incident light striking the edge of Estar base is propagated through the base and is attenuated only gradually by absorption within the base and by refraction at the gel interfaces.

Any light refracted out into the emulsion fogs the film. This may take the form of a fog density uniformly decreasing with distance from the edges or, under certain geometric and optical conditions, the light may be lost from the support to the gel layers in a repeating wave form, resulting in a striated fog pattern.

The high efficiency of light propagation through Estar base, compared with cellulose ester base, is the same as in polymethyl methacrylate and certain other plastics. Here, the phenomenon is utilized in medical applications, such as the bronchoscope, or as rod extensions on flashlights. This effect is evident on viewing a roll of Estar base film from the side, where light transmitted through the edges of the film base is visible.

These effects are illustrated in exaggerated form in Figure 11–5 which shows the fog produced in various films that have all been given the same edge exposure in a laboratory comparison test. These films, shielded on the emulsion and base sides, were given a controlled exposure, with the illumination directed at the cut edge of the films. While there is a fixed, inherent characteristic of Estar base to "pipe" light, the actual depth of fog penetration is influenced by the emulsion speed. As the "piped" light attenuates with distance the threshold exposure of slower emulsions is reached sooner. This is indicated by the lesser penetration of fog in the slower Experimental High Definition (SO-132) and Experimental Panatomic-X (SO-130) Aerial Films, compared with the Experimental Plus-X (SO-102) Aerial Film, though all are on the same Estar base.

Penetration is likewise affected by any absorbing or diffusing addenda in the base, such as haze, dye, or pigment. The gray cellulose triacetate base very effectively stops the light penetration, as illustrated with Special High Definition Aerial Film (SO-243) in Figure 11-5.

The above laboratory test is deliberately exaggerated. Figure 11–6 illustrates the effect of the base type on edge fog penetration under more practical conditions. Rolls of film with a clearance of 0.025 inch between the edges of the roll and the spool flange were exposed to an illumination of 2240 foot-candles for 4 minutes. A certain amount of the light was reflected from the inside of the flange at the proper incident angles to penetrate the film base and fog the emulsion, as illustrated. The Estar base film shows slightly deeper penetration than the triacetate base films.

The increased fogging potentiality of polyester base films points out the need for prevention of accidental edge exposure. However, in normal practice aerial films are wound on flanged spools and loaded in cameras or magazines in the dark or in subdued light. Under these conditions edge fog, even with polyester base film, is not a problem.

E. IMAGE DEFINITION

The higher refractive index of Estar base compared with cellulose ester bases, may result in very slightly lower definition under some special circumstances. This is primarily because the ratio of the refractive indexes of the gel layer–Estar base combination is greater than this ratio for the gel layer–cellulose ester base combination.

This effect is not significant in the case of camera negatives, as the image is normally formed by exposure of the emulsion surface. Resolution would only be affected by light penetrating the unprocessed emulsion, with reflection from the back of the base or the back of an anti-halation gel layer. Thus, in camera negative films, the type of base has no significant effect on image quality.

In the case of contact printing, in which the illumination comes through the base, optical characteristics of the base may have a small effect. Microscopic examination of resolution-chart images printed through both Estar and cellulose ester bases shows no difference in sharpness, for film of normal resolution. As would be expected, images printed with specular light are sharper than those printed with diffuse illumination, for both types of base. In the unusual case of successive generations of duplicating by contact printing, using film of very high resolving power (e.g., SO-105), some small loss in definition occurs.

The following table illustrates that with a very high resolution film, a greater loss occurs in contact printing by specular than by diffuse illumination. It also shows the difference in loss for the two types of bases.

First Negative	First Print		Second Negative	
	Specular	Diffuse	Specular	Diffuse
Cellulose Ester Base 390 lines/mm	360	360	330	330
Estar Polyester Base 390 lines/mm	330	360	270	330

Both before and after exposure and processing, the emulsion has some turbidity; consequently, some light is always traveling towards both surfaces at varying angles. It is this light that is multiply-reflected to produce the image degradation.

TABLE 11-I
TYPICAL HAZE MEASUREMENTS
(ASTM METHOD D 1003-59T, PROCEDURE A)

Film Base		Per Cent Haze
Cellulose acetate butyrate		0.5
Cellulose triacetate		0.5
Estar polyester		0.5
Emulsion Coated Films (processed without exposure)	**Emulsion Type**	
Kodak Plus-X Aerographic Film	5401	0.8
Kodak Plus-X Aerecon Film	8401	1.0
Kodak Plus-X Aerecon Film (Thin Base)	8402	9.0*
Kodak Aerographic Duplicating Film	5427	0.4
Kodak Special High Definition Aerial Film	SO-243	0.5
Kodak Experimental High Definition Aerial Film (Estar Thin Base)	SO-132	8.5*
Kodak Experimental Panatomic-X Aerial Film (Estar Thin Base)	SO-130	10.4*
Kodak Experimental Plus-X Aerial Film (Estar Thin Base)	SO-102	8.5*
Kodak Experimental Duplicating Film (Estar Thick Base)	SO-117	11.9*

*Matte in emulsion or gel backing

Figure 11-1
Spectral Transmittance
of Kodak Aerial Film Bases
(Ultraviolet)

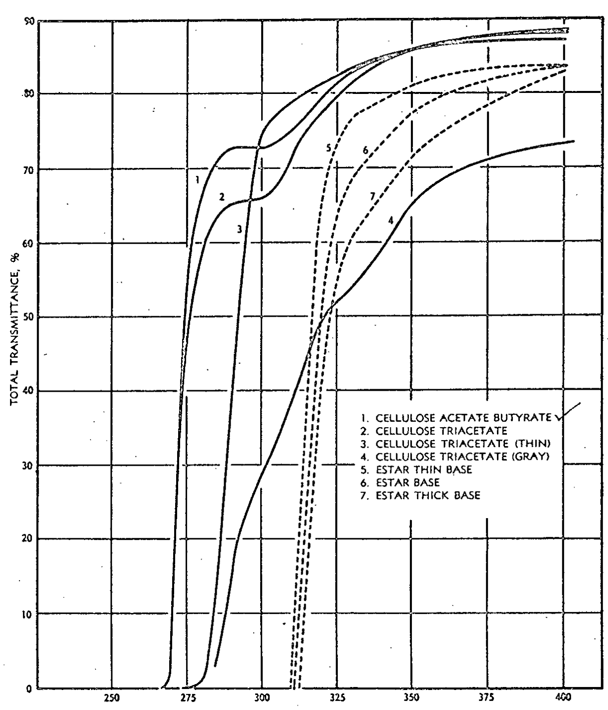

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Figure 11-2
Spectral Transmittance
of Fixed Out Kodak Aerial Films
(Ultraviolet)

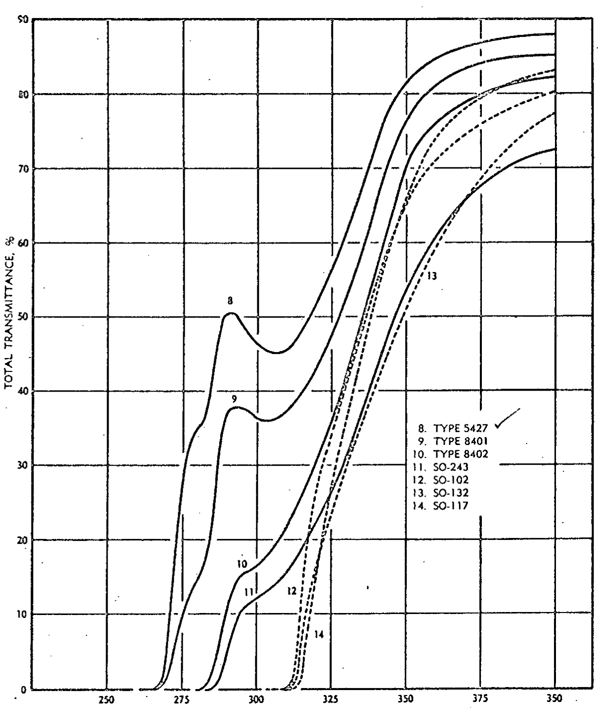
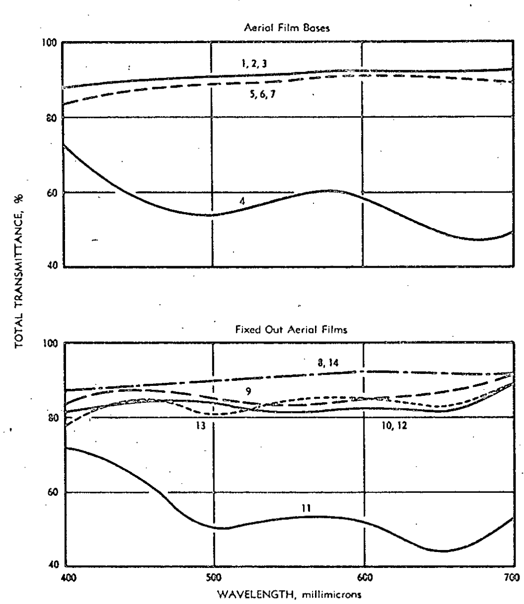


Figure 11-3
Spectral Transmittance
(Visible)

Legend—See Figs. 11-1 and 11-2



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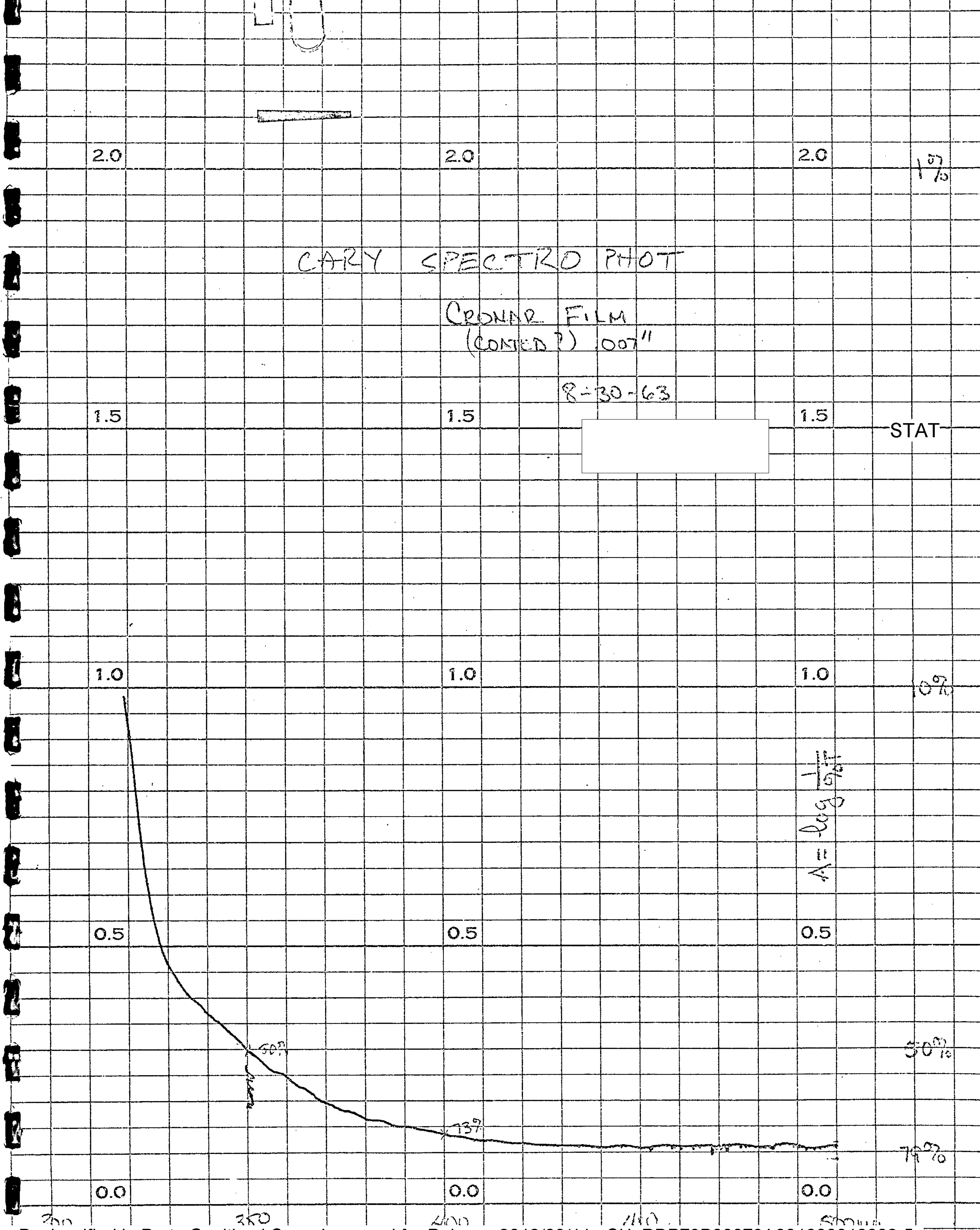

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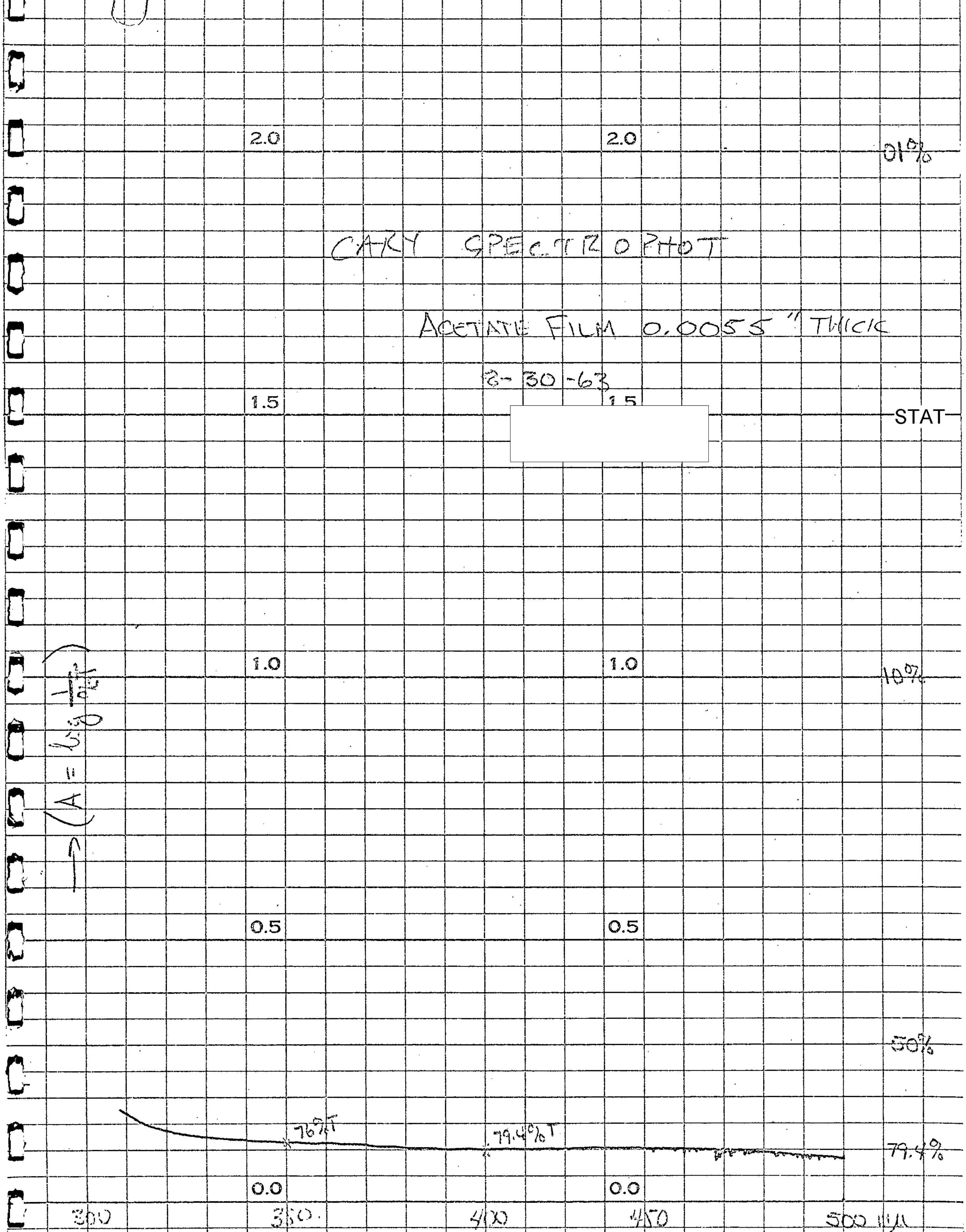

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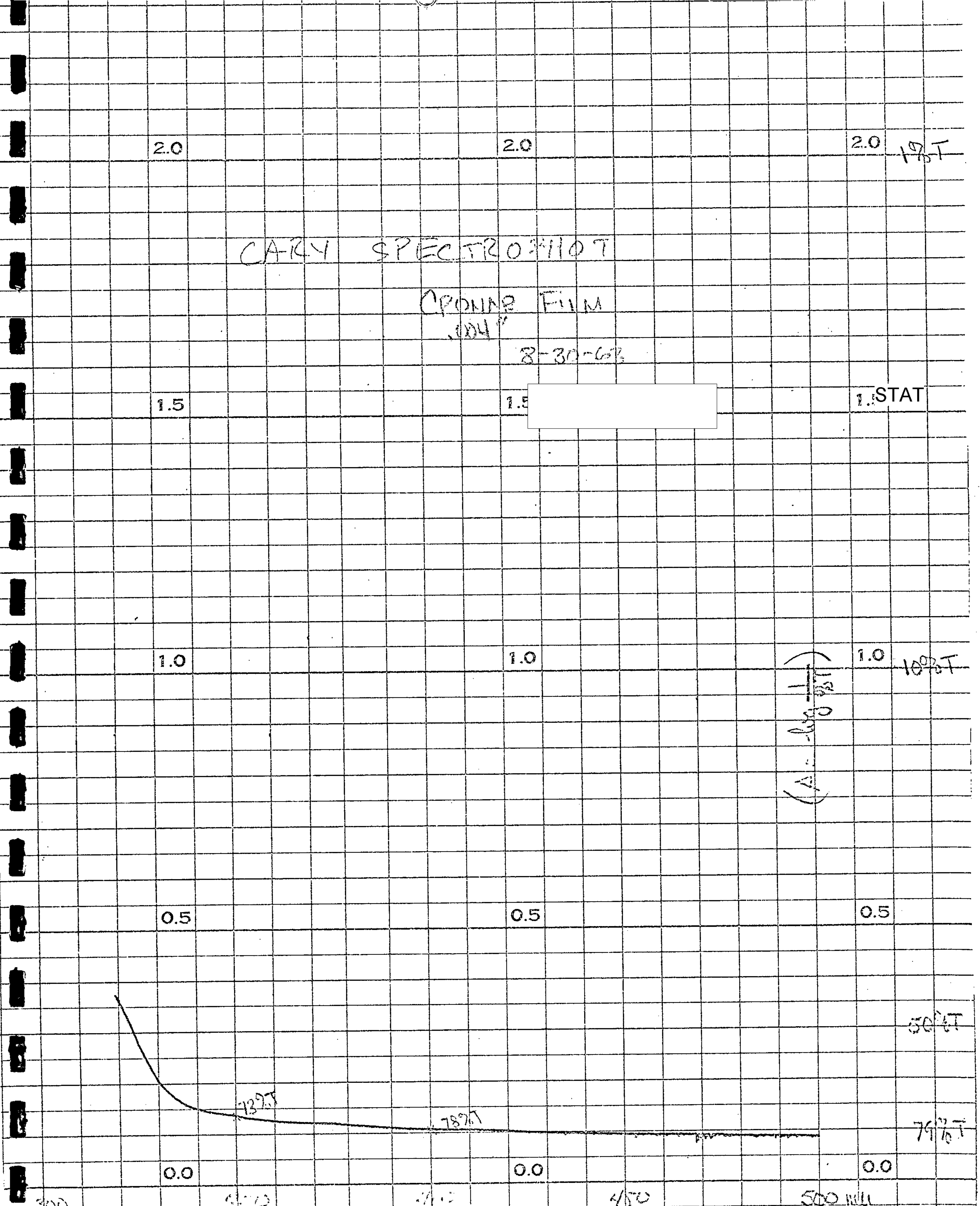
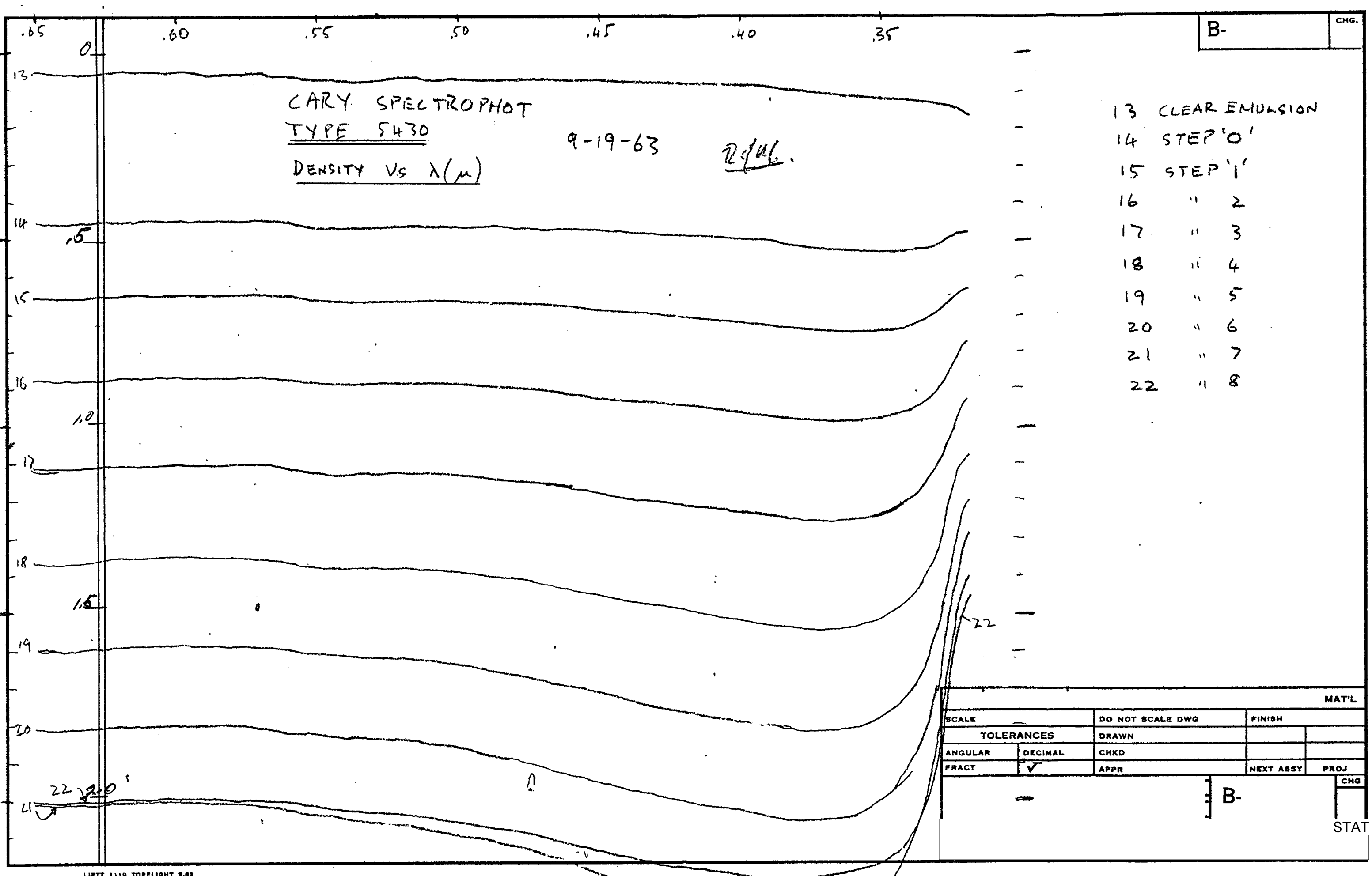

CARY SPECTROPHOT
CRONAR FILM
.004"
8-30-63
STAT
2.0
1.5
1.0
0.5
0.0
1%T
10%T
50%T
79%T
78%T
300
450
500 mμ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CARY SPECTROPHOT
TYPE 5430
DENSITY VS λ(μ)
9-19-63
13 CLEAR EMULSION
14 STEP '0'
15 STEP '1'
16 " 2
17 " 3
18 " 4
19 " 5
20 " 6
21 " 7
22 " 8
13
14
15
16
17
18
19
20
21
22
B-
CHG.
MAT'L
SCALE
DO NOT SCALE DWG
FINISH
TOLERANCES
DRAWN
ANGULAR
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APPR
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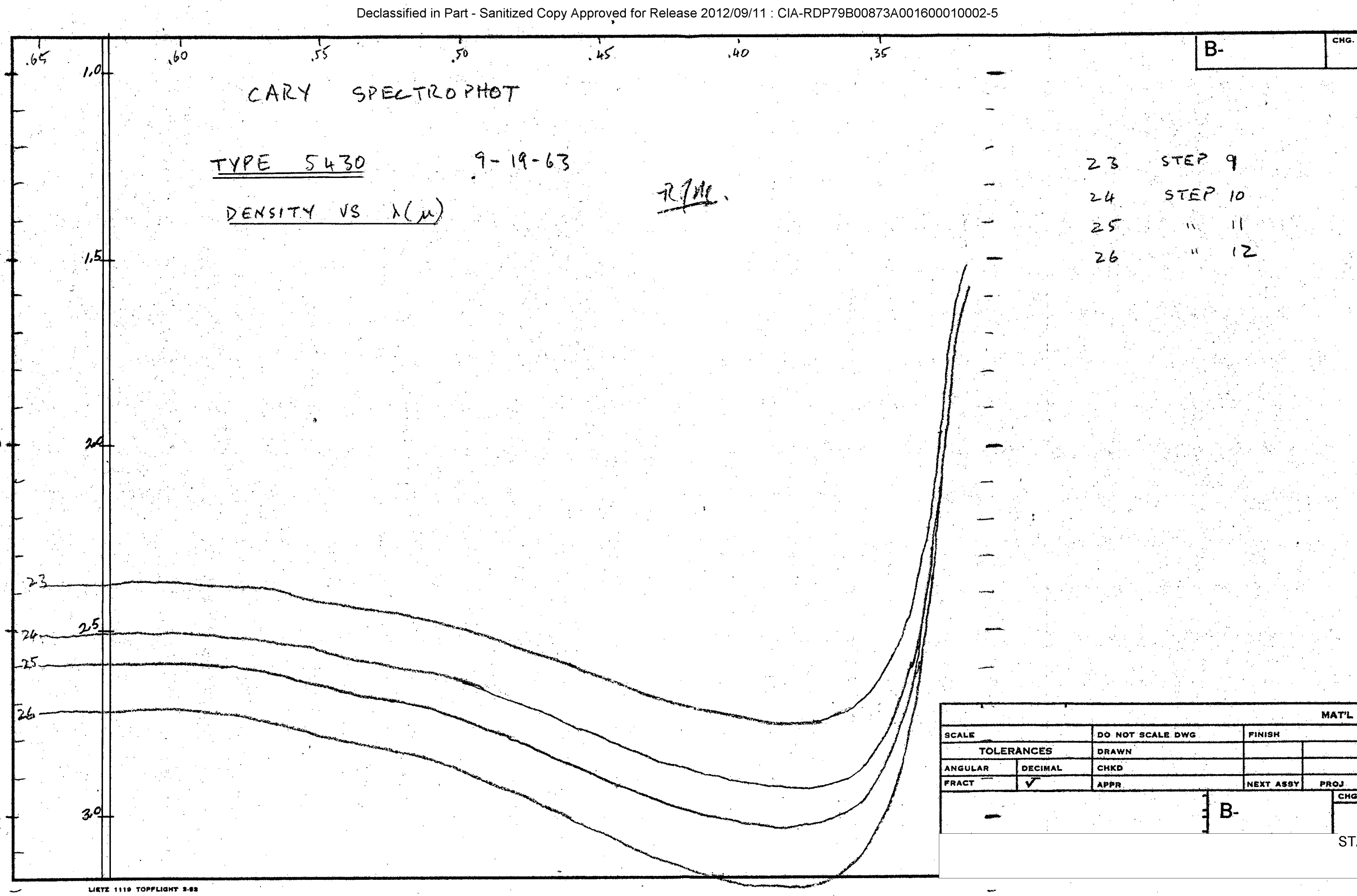
LIETZ 1110 TOPFLIGHT 3-62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TYPE 5430
9-19-63
DENSITY VS λ(μ)
23 STEP 9
24 STEP 10
25 " 11
26 " 12
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CHG.
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DO NOT SCALE DWG
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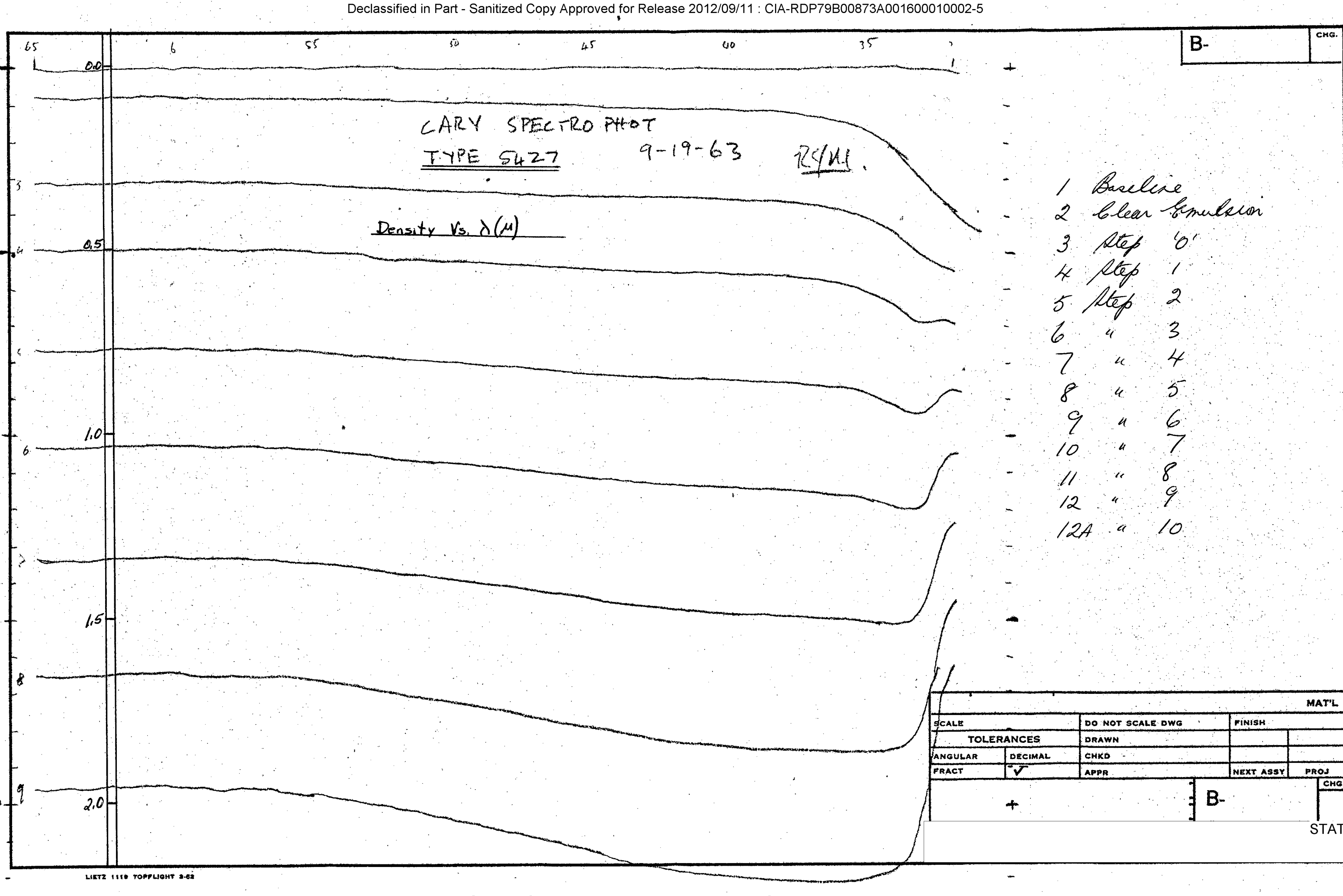

B-
CHG.
CARY SPECTRO PHOT
TYPE 5427
9-19-63
Density Vs. λ(μ)
65
6
55
50
45
40
35
0.0
0.5
1.0
1.5
2.0
1 Baseline
2 Clear Emulsion
3 Step '0'
4 Step 1
5 Step 2
6 " 3
7 " 4
8 " 5
9 " 6
10 " 7
11 " 8
12 " 9
12A " 10
MAT'L
SCALE
DO NOT SCALE DWG
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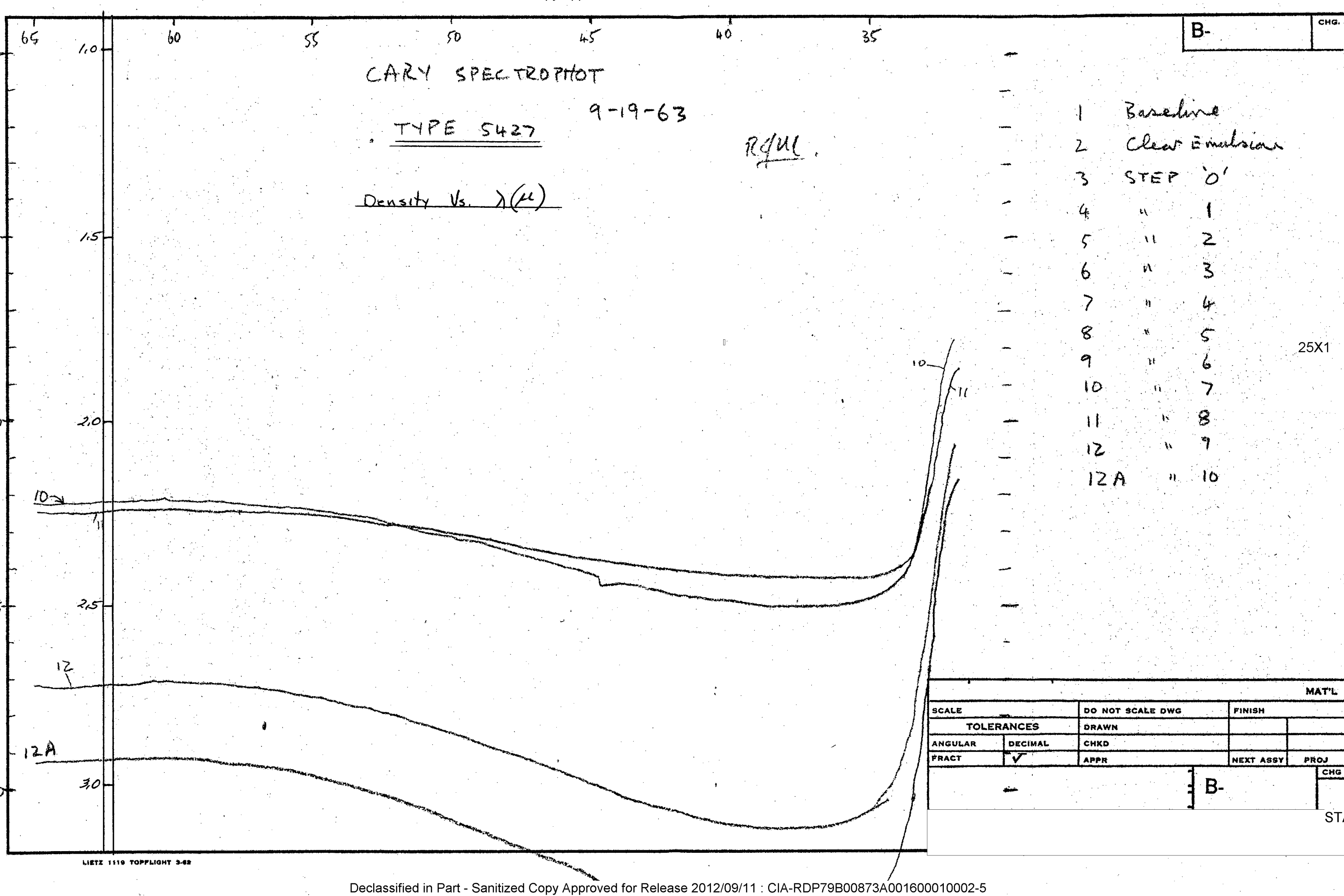
B-
CARY SPECTROPHOT
9-19-63
TYPE 5427
Density Vs. λ(μ)
1 Baseline
2 Clear Emulsion
3 STEP '0'
4 " 1
5 " 2
6 " 3
7 " 4
8 " 5
9 " 6
10 " 7
11 " 8
12 " 9
12A " 10
65
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CAPABILITIES

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SYSTEMS ENGINEERING BULLETIN

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SYSTEMS ENGINEERING
BULLETIN 3217
AUGUST 1, 1963

ORGANIZATION AND MANAGEMENT

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

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INTRODUCTION

Systems for electronic data processing, measurements in space, ground support and checkout, control of fast-response processes, dynamic and static testing – these represent the business of [redacted]. To meet the special requirements of systems development, design, and fabrication, a distinctive organization has been evolved. To man this organization, a new breed of systems engineer–business man has been bred.

[redacted] systems are distinguished by the fact that all necessary fields of technology are used to accomplish the desired end-result – that is, a system may utilize not only electronic means, analog and digital, but also pneumatic, hydraulic, mechanical, optical, and other elements. Consequently, each system represents the composite efforts of many specialists, contributing highly developed skills within their specialties, all joined in a teamwork which results in top-quality equipment.

[redacted] has worked out, over almost ten years of system-building experience, a method of project management – backed up by a structure of corporate organization – which has proved highly effective for the design and production of special-purpose systems. Each system project is placed under the direction of a project chief, a systems engineer by profession, a project manager by experience.

Total responsibility for the successful completion of the system rests with the project chief. He handles the engineering function directly; other functions necessary to manufacture the system are represented by specialists assigned to assist him. For example, production planning is carried out by a member of the manufacturing organization, detailed to the project, who is responsible for the efficient application of all manufacturing resources to assure the successful execution of the project on schedule.

COMPANY HISTORY

In February 1954 two engineers and two secretaries were separated out of the engineering department of [redacted] to form the nucleus of the [redacted] Soon joined by others, the systems team that first year did $200,000 worth of business. From the very first, four threads of activity may be distinguished which have carried through to the present day.

One is the application of sophisticated analytical instruments, such as the mass spectrometer, to the measurement needs of science and industry. This thread is currently represented by the two mass spectrometers carried by Explorer 17, measuring atomic and molecular particles found in space.

The second area originated in the engineering activities leading to the development of a system to reduce the telemetered data generated by early missile test flights. The time required to reduce the flight data was shortened to one-tenth the time former methods had consumed. As engineering test activities expanded manyfold to keep up with mounting research and development, this systems area developed to meet the need for more efficient data acquisition and processing systems. Now an extensive series of MicroSADIC-type systems – the latest successors to the historic SADIC and MilliSADIC systems – meet every data processing need.

The third thread had to do with the generation, measurement, and control of pressure – often extended to include other variables such as temperature. [redacted] tems were designed to test the complex pressure and pressure-ratio parameters of liquid-fuel missiles, culminating in large contracts for the production of a series of pneumatic test sets for the Atlas.

The fourth theme was the integration of sensors and actuators with a feedback loop to form control systems. From single-loop electromanometer systems to measure pressure, this field developed into the complex, multi-loop systems required to control the numerous variables found in installations such as a jet-engine test stand.

In 1959 the [redacted] was incorporated [redacted], and in 1960 [redacted] corporation became associated through ownership interests with [redacted] The associations lead to one new thread and greatly strengthened an earlier thread of activity.

The new thread was electro-optical systems, formed by fusing [redacted] military cameras [redacted] photographic–recording systems and [redacted] optical products facility with [redacted] electronic and mechanical systems know-how. [redacted]rently, the digital optical tracker, consisting of an optical telescope, a digital computer, and feedback drive to the telescope mount, exemplifies the complex interdisciplinary systems found in this area.

The strengthened thread was industrial systems. While [redacted] had from the beginning produced systems for industrial applications – the first completely automated, computer-controlled miniature pilot plant to evaluate solid-catalyst processes was a [redacted] system – the association with [redacted] gave new impetus to the effort to penetrate industry with systems. Installations in steel rolling mills, a peaking power plant, and dry processes now attest to the vigor of this association.

Twisting through all these threads, an essential element in [redacted] systems, is electronics – programming, controlling, processing information. Conscious of the indispensability of electronics, [redacted] operates its own printed circuit manufacturing facility, maintains a line of standard NOR/NAND digital logic cards, and fabricates its own standard racks, cabinets, and consoles.

THE ASSOCIATE COMPANIES

[redacted] is an associate company of three of America's best-known companies: [redacted] As a corporation, [redacted] is legally separate and independent; as an associate, it is linked through stock ownership with these three companies. [redacted] corporate stock is held 50 percent by [redacted] and 50 percent by [redacted] is in turn a 100 percent subsidiary of [redacted] The board of directors of [redacted] tion consists of executives of each of the three associate companies plus the president and vice president-general manager of [redacted]

As an autonomous corporation [redacted] enjoys the freedom of operation necessary to function successfully in the fast-moving systems business – to design and produce one-of-a-kind systems in minimum time. At the same time, as an associate of three major industrial corporations in diverse fields, [redacted] has the advantage of technical relations, contractual capability, and financial support.

[redacted] designs and produces a wide range of basic and auxiliary industrial equipment for many fields. These industries include metal rolling, dry processes, and electric power generation – steam, water, and atomic – in which [redacted] have pursued joint programs of industrial systems.

[redacted] is the world's largest manufacturer of 16mm motion picture equipment. Their experience in this industry has resulted in a capability to integrate optical, mechanical, and electrical elements for photographic purposes. Building on this base, and adding electronic and control technology, [redacted] has created a competence in electro-optical systems.

[redacted] is a leader in instrumentation, known for its analytical instruments, transducers, data recorders, and vacuum equipment. Many [redacted] products are incorporated in [redacted] systems where they best fit the application, but [redacted] systems engineers are charged with selecting the product best suited for the system at hand, regardless of source.

The [redacted] in nearby Pasadena is engaged in basic and applied research in technical areas of interest to [redacted] and [redacted] These fields include physics, chemistry, optics, electronics, solid-state materials, thin-film techniques, and behavior of materials at cryogenic temperatures.

ORGANIZATION

[redacted] is divided into three major functions, several administrative departments, and two product divisions. The functions are Engineering, Field Engineering, and Operations; the product divisions are Optical Products and Printed Circuits.

The Engineering function is organized into four systems engineering departments and a common Engineering Services department. The lines between the engineering departments are not rigid as the nature of systems work requires that specialists from each department contribute their particular skills to projects as needed.

Field Engineering represents the systems capabilities of the company to customers through field engineering representatives stationed in principal technical centers throughout the United States. Contract Administration, Public Relations, and Field Service Engineering are organizationally located within this function.

The Operations function provides a unified organizational framework to oversee the building of systems; this function covers Planning and Production, Materiel and Purchasing, and Quality Assurance.

The Administrative departments include the Treasurer's Office, Finance, Budgets, and Accounting; Security and Services; and Personnel. Each performs company-wide duties in its field.

The two product divisions, Optical Products and Printed Circuits, each include the functions of marketing, planning, production, and quality assurance in order to facilitate efficient day-to-day operation. The central corporation provides assistance in these functions and services in the other organizational fields. While each product division has independent customers for its products, each also provides the corporation with important in-house prototype and manufacturing capabilities for inclusion in systems.

SYSTEMS ENGINEERING ORGANIZATION

The engineering of modern systems requires broad capabilities in many technical areas and organizational arrangements able to apply these specialties at the time and place needed. Departmental functions are summarized as follows:

Space Sciences: Instrumentation for electromagnetic spectrum and particle analysis in space; space command systems; instrumentation checkout; electronic, mechanical, and laboratory support.

Digital Systems: Facility instrumentation systems; digital systems and components; weapon checkout systems; telemetry data processing systems.

Electromechanical Systems: Hydraulic and pneumatic systems; indicating and control systems; precision pressure systems; analog recording systems; analog programming systems; analog test facility instrumentation; precision-optics instrumentation; photographic instrumentation systems.

Industrial Systems: Analog and/or digital process control systems; computer controlled systems; tape-recorded information retrieval.

Engineering Services: Drafting, documentation, technical publications, repairs, spare parts and logistic support.

Cutting across the specialized technical fields are company-wide programs in reliability, maintainability, and value engineering.

PROJECT ORGANIZATION

Every technical organization faces the continuing necessity of solving a simultaneous equation of organization in two variables: one is the need to apply expert knowledge to the management of each line function – engineering, production, quality assurance, etc.; the second is the necessity to assure effective attention to each project – attention composed both of technical understanding and schedule-and-cost consciousness. In a systems company these organizational variables are magnified, because the most advanced state-of-the-art knowledge must be continuously applied in each function, and because simultaneous projects place a premium on efficient coordination.

[redacted] organization for systems is based on the project chief concept, illustrated in simplified form in Figure 1. STAT

On the project organization chart the solid lines represent the line authority of management; the dashed horizontal line represents the project authority of the project chief.

In advanced systems work, the way in which the engineering function is organized is fundamental to the success of the project. Key engineering personnel, experienced in the main technical fields of the project, are placed under the direct supervision of the project chief; direct responsibility leads to concentrated emphasis and continuity of effort over the duration of the program. At the same time, [redacted] flexible organizational arrangements permit specialists from other engineering units to be added to the project on a planned basis to work in their specialties for the period of time needed. When unanticipated difficulties are detected, the organization's flexibility of response is extended still further by re-assigning or bringing in engineering specialists to meet the new need. STAT

Figure 2, Key Systems Activities, shows in more detail the functions the project chief supervises and coordinates during the system cycle. The engineer designated to be project chief on a system carries the primary responsibility for the contract from the initial proposal through all the steps of engineering and

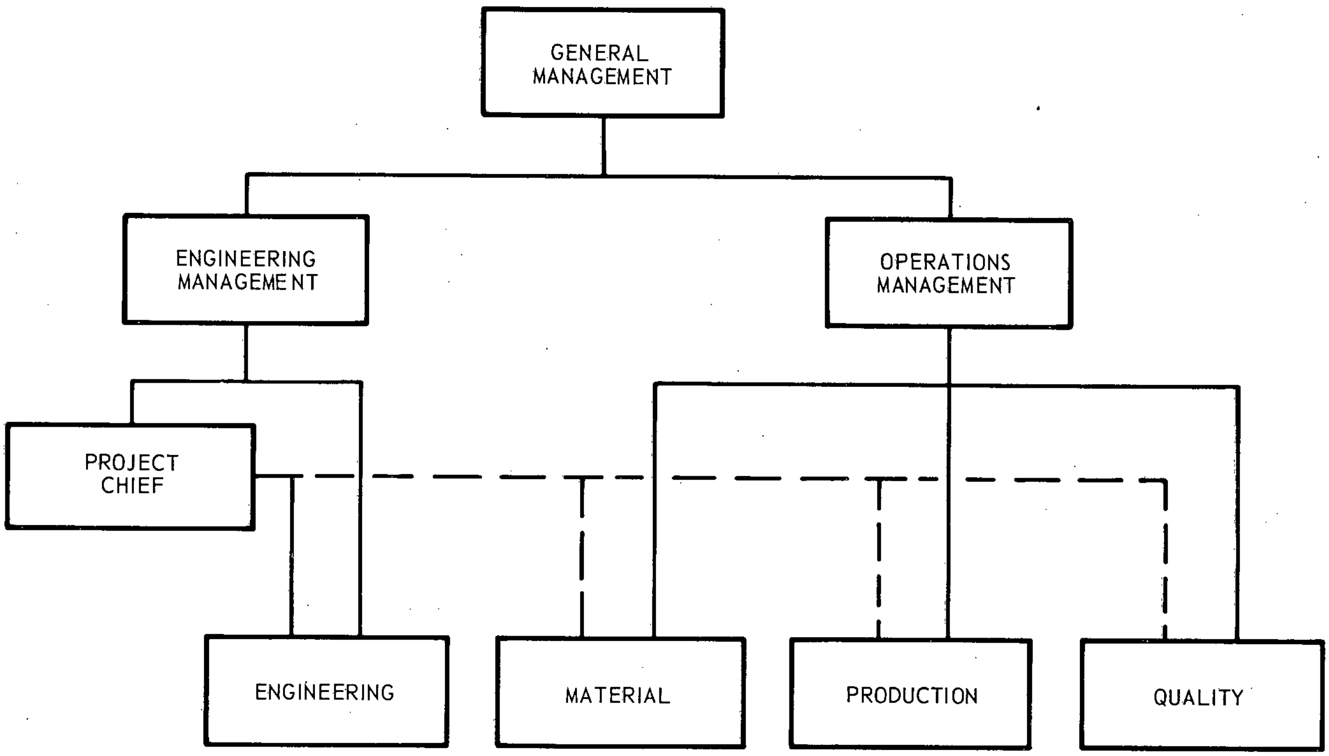

FIGURE 1.
Project Organization

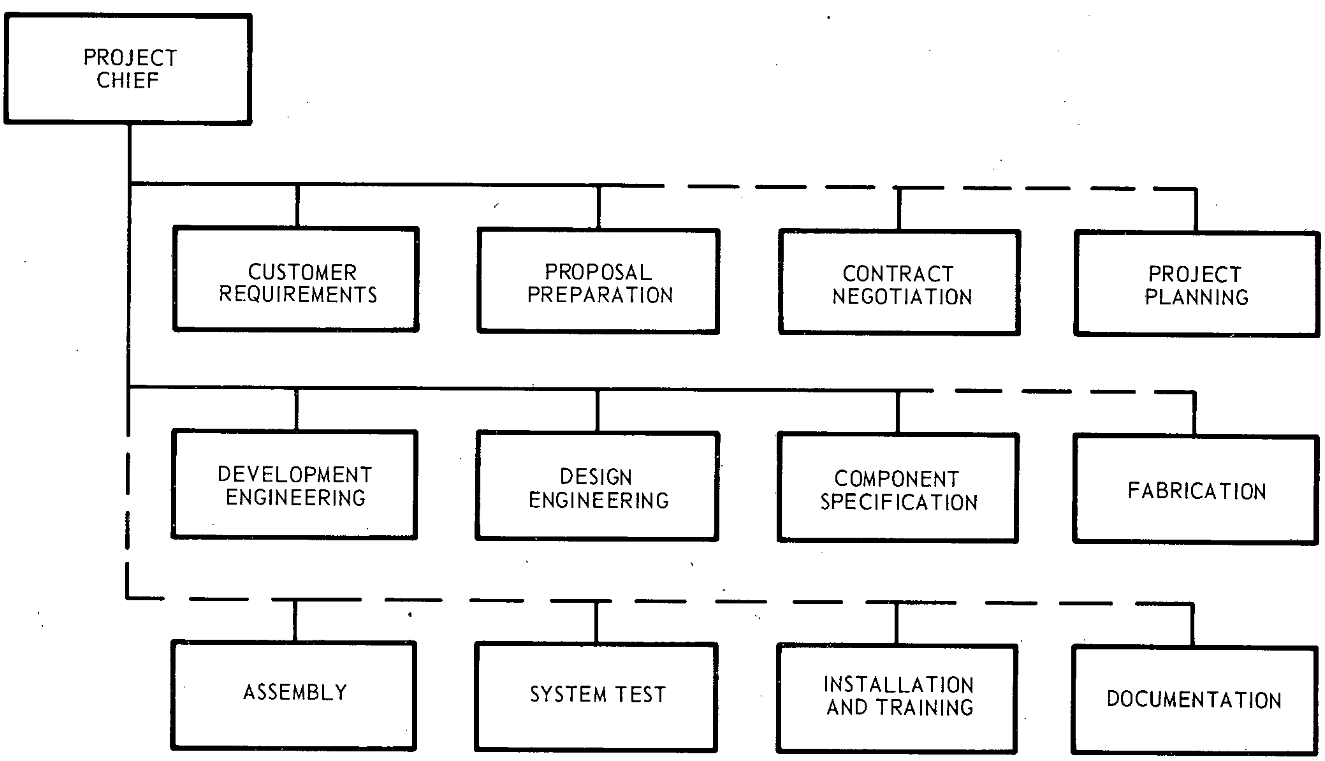

FIGURE 2.
Key Systems Activities

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manufacturing to acceptance of the hardware by the customer. While the project chief exercises direct supervision over the engineering personnel assigned to the project, the personnel in the other functions report also to a line supervisor who is responsible for the efficient performance of the function. By understanding the whole project picture, by maintaining contact with the customer and his needs, and by possessing a strong technical comprehension of the system, the project chief is in a position to lead from strength. His leadership is solidly based on superior project and technical knowledge.

The project chief heads a team of assigned individuals representing the principal departments concerned with the production of the particular system. The team members help him bring all the force of the company behind the accomplishment of the contract.

A typical project team might look like this:

Department Represented	Member of Team	Aided By
Engineering	Project Chief	Engineers, Aides, Designers
Production & Planning	Project Foreman	Planner, Leadman
Quality Assurance	Test Supervisor	Technicians
Purchasing	Buyer	Follow-up Personnel
Contract Administration	Administrator	Cost Analysts

Many company-wide functions supply services to all project teams and are not normally represented on the project team –

- Accounting
- Material Control and Stock Room
- Quality Control: Incoming, In-Process, Bench, Line, and other Inspection
- Shipping, Receiving
- Component Manufacturing Departments: Printed Circuit Boards, Optical Products, Machine Shop, Sheet Metal Shop, Paint Shop, Cabling

To relieve the project chief and his senior engineering associates of detail work, engineering aides are assigned to the project to prepare wiring diagrams, wiring lists, and specifications, as well as to facilitate technical liaison with production and test personnel. The Engineering Services department supplies design and drafting support, prepares documentation and manuals, and compiles spare parts requirements.

The project foreman with his assistant, the production planner, both working in close contact with the project chief, establishes the fabrication and assembly operations and processes to be employed, prepares a plan scheduling these operations, commits the personnel and material resources of the Production Department to meet the system schedule, and requisitions materials, parts, and outside production. A buyer fills these requisitions from the most competent suppliers at prices and deliveries consistent with the project performance requirements; he follows up delivery commitments and monitors vendor performance.

The test supervisor and other Quality Assurance personnel, on the basis of the contract and engineering prints and specifications plus company quality standards, determine inspection requirements and monitor production quality. Both inside and outside production are quality-controlled through inspection and system performance is checked by engineering test to assure that the contractual requirements of the project are fully achieved.

Specialized contract administrators and cost analysts assist the project chief on contract administration, budgets, and cost analysis.

To make this project organization concept work for all contracts in the company calls for conscientious attention – and corresponding action – on the part of the department managers responsible for the functional units. Each department manager is responsible for following the needs of all projects he is servicing and for acting to meet those needs – by re-assigning personnel or equipment, or by expanding the resources applied – in order to maintain all project schedules.

PROJECT PLANNING AND CONTROL

To bring responsibility to planning, [redacted] early in its STAT history fused the planning function and the doing function. The difficulty of having one person meet a schedule which another person made was clearly recognized. The organization was patterned so that the committer became the doer – there can be no shorter line of communication.

The project chief is the over-all planner, the project foreman – a member of the project team – is responsible for planning production. In practice he may be assisted by a full-time production planner, but this planner is the direct subordinate of the project foreman, and the foreman remains fully responsible for both planning and execution.

The means for planning each project – and then exercising control over its execution – is the Contract Control Schedule. Figure 3 is a reduced copy of the form. The project chief prepares this control schedule immediately after the receipt of the contract, obtaining expert assistance from the project foreman, test supervisor, buyer, contract administrator and other members of the project team in their individual areas. The completed Contract Control Schedule becomes, in effect, the master plan for the execution of the contract; copies are reproduced and distributed to project members and all affected departments.

Each project is broken down into tasks and sub-tasks. The project is identified by a register number and the tasks by dash numbers. The four essentials of project control – budget, time schedule, costs, and time execution – are then keyed to the task dash-numbers. Opposite each dash number on the contract control schedule, material dollars and manhours for each type of labor are entered; these columns constitute the project budget. Milestones for each task are posted by means of code letters representing the type of event; this becomes the project time schedule. Costs are collected by dash numbers. Task completion is monitored against the schedule.

Thus, the contract control schedule brings together in one place, accessible to all concerned, the fundamental information necessary to control a project: the task breakdown, the task budget, and the schedule of milestone events for each task. This method of project control has been followed at [redacted] for many years. It evolved out of the company's initial systems-building experience and it has been refined to a very effective tool over the intervening years.

The information on the contract control schedule pertaining to task and schedule can readily be converted to PERT network presentation by analysis of the sequencing of tasks by the project group; similarly, the accumulation of costs by task dash-number for comparison against the task budgets is essentially the same cost technique as PERT-Cost.

To assure that all necessary technical and administrative skills are being brought to bear promptly on each project, [redacted] management conducts a project review every two weeks. With the close participation of the project chief, the responsible engineering manager – for experience indicates that most systems problems have a technical aspect – carefully examines all facets of the project. Performance requirements are compared to progress to date; engineering, production, materiel, and quality schedules are coordinated; up-to-date cost data is analyzed in relation to the contract budget, and cost-to-completion within the scheduled time is re-checked. Other members of the project team and functional department managers are called into the review as necessary.

When project review indicates trouble impending in any area, or when the cost accumulation begins to outrun the budgeted funds, immediate action is initiated to solve the difficulty at its source. Personnel may be re-directed, or additional personnel assigned. Consultants may be retained. Additional space or other resources may be arranged. The result of each project review is recorded on a special form, Project Status Review, shown in Figure 4.

In serious troubles involving several areas of the program, a management technique known as the "task force" has been employed. This technique differs only in degree of urgency from normal project management methods: a corporate officer, for example, may be assigned to head a task force; senior personnel with the most pertinent experience are attached to the task force as their primary duty. The purpose of task force management – on urgent priority – is to cut through all difficulties, get the project back on schedule, and return it to normal project supervisory channels.

ENGINEERING PERSONNEL

A company's ability to reach its goal – to build better systems – and to realize the promise in its philosophy of organization depends upon the quality and dedication of its people. The concept of the responsible project chief, conscientiously supported by the functional departments, all working together to deliver better systems, can be brought to full realization only through qualified personnel in every classification.

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There is inherent in the nature of the systems business an attraction for capable, mature engineers and manufacturing personnel; the attraction lies in the succession of systems, each one different from the last one, each one an opportunity for new experience. Capitalizing on this attraction, [redacted] form of organization, by combining the continuing challenge with a heavy load of personal responsibility, generates the kind of assignment that the practical get-things-done individual seeks out. [redacted] has a high proportion of such men, raised within the company from young engineers, now qualified both as systems engineers and project managers.

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The level of education, type of degree, and years of experience of the company's engineering personnel are tabulated below:

Education:

Master's Degree	13
Bachelor's Degree	56
College – less than degree	40
No College	0
Total	109

Types of Degrees:

Electrical	46
Mechanical	10
Chemical	2
Physics	8
Aerodynamics	2
Mathematics	1
Total	69

Engineering Experience:

1 - 5 years	42
6 - 10 years	30
11 - 15 years	20
16 - 20 years	9
21 and over	3
Total	109

S [redacted] STAT

AVAILABLE EQUIPMENT AT [redacted] STAT

There are currently 6 vacuum systems (excluding mass spectrometers and leak detectors) in operation, of which 3 are in use for evaporation of thin films. Typical materials being coated are cadmium sulfide, aluminum, gold, silicon monoxide, indium, nickel, tin and iron.

Optical analysis capabilities are divided between the organic chemistry, solids mass spectrometry, and photographic materials groups. These include:

1. a Cary Spectrophotometer (U-V and visible),
2. a Beckman D-U spectrophotometer,
3. a Perkin-Elmer double beam infra-red spectrophotometer,
4. Macbeth quantalog densitometer,
5. B & L monochromator,
6. B & L 1.5 meter spectrograph,
7. B & L Colorimeter,
8. a B & H Research-built wide aperture spectrograph,
9. numerous microscopes and Photovolt photometer.

Single crystals of various compounds such as gallium arsenide are regularly produced by zone refining and their purity checked with our [redacted] solids STAT research mass spectrometer.

PERSONNEL RESUMES

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Next 9 Page(s) In Document Denied